PAPERS PRESENTED TO

NEW DEVELOPMENTS REGARDING THE KT EVENT AND OTHER CATASTROPHES IN EARTH HISTORY

February 9–12, 1994

Houston, Texas

Sponsored by
Lunar and Planetary Institute
University of Houston–Clear Lake

LPI Contribution No. 825

PROPOSED LAW OF NATURE LINKING IMPACTS, PLUME VOLCANISM, AND MILANKOVITCH CYCLES TO TERRESTRIAL VERTEBRATE MASS EXTINCTIONS VIA GREENHOUSE-EMBRYO DEATH COUPLING. D. M. McLean, Department of Geological Sciences, Virginia Polytechnic Institute, Blacksburg VA 24061, USA.

A greenhouse-physiological coupling killing mechanism active among mammals, birds, and reptiles has been identified. Operating via environmental thermal effects upon maternal core-skin blood flow critical to survival and development of embryos, it reduces the flow of blood to the uterine tract. Today, during hot summers, this phenomena kills embryos on a vast, global scale. Because of sensitivity of many mammals to modern heat, a major modern greenhouse could reduce population numbers on a global scale, and potentially trigger population collapses in the more vulnerable parts of the world. In the geological past, the killing mechanism has likely been triggered into action by greenhouse warming via impact events, plume volcanism, and Earth orbital variations (Milankovitch cycles).

Earth's biosphere is maintained and molded by the flow of energy from the solar energy source to Earth, and on to the space energy sink (SES) [1]. This SES energy flow maintains Earth's biosphere and its living components, as open, intermediate, dissipative, nonequilibrium systems whose states are dependent upon the rate of energy flowing through them. Greenhouse gases such as CO_2 in the atmosphere influence the SES energy flow rate. Steady-state flow is necessary for global ecological stability (autopoiesis).

Natural fluctuations of the C cycle such as rapid releases of CO_2 from the mantle, or oceans, disrupt steady-state SES flow. These fluctuations constantly challenge the biosphere; slowdown of SES energy flow drives it toward thermodynamical equilibrium and stagnation. Fluctuations induced by impact events, mantle plume volcanism, and Milankovitch cycles can grow into structure-breaking waves, triggering major perturbations of Earth's C cycle, and mass extinctions.

A major C cycle perturbation involves readjustment of the outer physiochemical spheres of the Earth: the atmosphere, hydrosphere, and lithosphere, and by necessity, the biosphere. A greenhouse, one manifestation of a major C cycle perturbation, is the most dangerous natural phenomenon that life of Earth can experience. Greenhouse conditions existed during the KT mass extinctions of 65 m.y. ago [2], and the Pleistocene-Holocene (P-H) mammalian extinctions of 10,000–12,000 yr ago. Coupling climatology to reproductive physiology via effects of ambient air temperature upon uterine blood flow to developing embryos accounts for the extinctions via established physiological principles.

The KT extinctions seem a function of both Late Cretaceous climatic cooling and KT greenhouse warming that began at or about the KT boundary. A negative $\delta^{13}C$ excursion indicates a major C perturbation, and a synchronous negative $\delta^{18}O$ excursion, climatic warming. The greenhouse lasted 200–300 k.y. into the Early Tertiary.

Two natural phenomena are candidates for the KT boundary greenhouse: the Deccan Traps mantle plume volcanism in India, and the Chicxulub structure on Yucatan, which has been attributed to extraterrestrial impact event. Ninety percent of the Deccan Traps' vast volume of tholeiitic lavas erupted 65 m.y. ago [3]. The Chicxulub structure has been dated at about the same age [4]. Massive KT CO_2 release via Deccan Traps eruptions [5], or impact [6], or impact-induced water vapor release [7] would have disrupted SES energy flow, triggering change of state of the biosphere manifested in the KT transition extinctions.

Other sources of KT transition CO_2-induced greenhouse conditions were failures of the Williams-Riley marine "pump" that removes CO_2 from the atmosphere-marine mixed layer and stores it in the deep oceans, and a KT transition marine transgression starting just below the KT boundary and extending through early Paleocene (130-m rise) [8] that flooded highly productive terrestrial plant ecosystems with low productive marine ecosystems [9]. The KT record contains no definitive evidences of an "impact winter" global blackout and refrigeration [10].

A key point in linking climate to embryo survival is that embryo damage and death can occur at environmental temperatures that pose little danger to adults. During hot conditions, adults shunt blood to the skin to transport body heat to the environment. This action reduces blood flow to the core and to the uterine tract. Blood flow to the uterine tract carries damaging metabolic heat away from developing embryos [11], and supplies critical O, H_2O, nutrients, and hormones [12]. Reduced uterine blood flow causes the uterine tract to overheat, damaging and killing fertilized eggs during the critical first cleavage. During later stages of development, reduced uterine blood flow can produce dwarfing and skeletal abnormalities. For modern pregnant, lactating European-type cattle, air temperature in the range of 70°–81°F (21°–27°C) causes the core temperature to rise. A rise in uterine temperature of 1.8°–2.7°F (1.0°–1.5°C) will kill most embryos. Study of air temperature vs. conception rates of 12,000 Florida cattle via artificial inseminations showed that on days when the air temperature following insemination exceeds 86°F (30°C), conception rates fall from 52% to 32%, and then stay low during the hot summer months [13].

Vertebrate adaptation to climate involves adjusting size and S/V ratios, body shape, insulation, and metabolism. Of the five, size is slowest to change in response to sudden climatic warming. Large Pleistocene mammals adapted to a cold ice age climate would have had difficulty getting rid of body heat during rapid warming. The main pulse of the P-H mammalian extinctions coincided with the abrupt warming about 11,700 yr ago that ended the last ice age (indicated in Greenland ice cores). Those extinctions eliminated primarily large "big game" mammals, and produced dwarfing and skeletal abnormalities, reflecting the "signature" of climatic heat effects upon uterine blood flow to developing embryos [14]. Milankovitch cycles drive the Cenozoic ice age cycles and also seem to influence mammalian bioevolution and extinctions.

Among birds, uterine blood flow is reduced by high environmental temperatures. Studies of modern chickens indicate that hyperthermia diminishes blood flow to the ovarian follicles by 40–50%, decreasing shell weight and quality, and reducing egg production [15]. During the P-H climatic warming at the end of the last ice age, large birds experienced more extinctions than any other group except large mammals [16]. In the face of rapid warming, cold-adapted large birds would have experienced hyperthermia. Hyperthermia-induced reduction of uterine blood flow to the follicles would have reduced fertility and egg production, triggering collapse of populations.

For moderate to large reptiles (including the dinosaurs), "gigantothermy," a thermoregulatory strategy based on use of large body size, low metabolic rate, peripheral tissues as insulation, and control of blood flow between core and skin [17], allows successful response to diurnal and seasonal climatic changes. Via such strategy, the modern leatherback turtle, the largest marine turtle (1000 kg), maintains body temperature of 86°F (30°C) in Arctic waters of 50°F (10°C), or less; it has a problem dumping heat in a warm terrestrial environment [17]. Dinosaurs that were adapting to Late Cretaceous climatic cooling would have, in the face of KT boundary greenhouse warming, experienced thermal stress, and likely uterine blood flow-induced reproductive problems. Hot summers rather than cold winters likely caused the disappearance of the dinosaurs [18].

Proposed law of nature: Climate control of uterine blood supply to the fertilized egg during first cleavage and later embryo development influence population dynamics, bioevolution, and extinction.

References: [1] Morowitz H. J. (1979) *Energy Flow In Biology*, Ox Bow Press. [2] McLean D. M. (1978) *Science, 201*, 401–406. [3] Basu A. R. et al. (1993) *Science, 261*, 902–906. [4] Sharpton V. L. et al. (1992) *Nature, 359*, 819–821. [5] McLean D. M. (1985) *Cretaceous Research, 6*, 235–259. [6] O'Keefe J. D. and Ahrens T. J. (1988) *LPS XIV*, 885–886. [7] Emiliani C. et al. (1981) *EPSL, 55*, 317–334. [8] Keller G. et al. (1993) *GSA Bull., 105*, 979–997. [9] McLean D. M. (1978) *Science, 200*, 1060–1062. [10] McLean D. M. (1991) in *Global Biomass Burning: Atmospheric, Climatic, and Biospheric Implications*, 493–503, MIT. [11] Gwazdauskas F. C. et al. (1974) *J. Anim. Sci., 39*, 87–92. [12] Senger et al. (1967) *J. Exp. Zool., 165*, 337–344. [13] Badinga L. et al. (1985) *J. Dairy Sci., 68*, 78–85. [14] McLean D. M. (1981) *Am. J. Sci., 281*, 1144–1152; (1991) in *Energy and Environment*, 93–100, ASHRAE. [15] Wolfenson D. et al. (1979) *Br. Poult. Sci., 20*, 167–174. [16] Steadman D. W. and Martin P. S. (1984) in *Quaternary Extinctions*, 466–477, Univ. Arizona. [17] Spotila J. R. et al. (1993) *Mod. Geol., 16*, 203–227. [18] Cloudsley-Thompson J. L. and Butt D. K. (1977) *Br. J. Herpet., 5*, 641–647.